**SUSY-Cosmology at LHC**

Alfredo Gurrola  
in collaboration with  
R. Arnowitt, B. Dutta, T. Kamon, A. Krislock,  
P. Siméon, D. Toback – Texas A&M  
N. Kolev – University of Regina

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**Cosmic Collision of Two Galaxy Clusters**  
*splitting normal matter and dark matter apart*  
– Another Clear Evidence of Dark Matter (8/21/06) –  

Exploring a possibility for detecting this Dark Matter  
at the LHC

- Dark Matter and Supersymmetry  
- Dark Matter Signal at the LHC
Cold Dark Matter (CDM) Particle

[1] Standard Model (SM) has not provided a solution.

[2] Supersymmetry (SUSY) extensions of SM naturally provide a weakly interacting massive particle that is stable: Lightest SUSY Particle (LSP)

Supersymmetry (SUSY)

[1] Fermion – Boson Symmetry

*Every standard model fermion (boson) has a boson (fermion) supersymmetry partner (example: X → \( \tilde{X} \))*

[2] This Fermion – Boson symmetry doubles the number of particles

\[ Z^0 \rightarrow \tau^+ \tilde{\chi}^0_2 \rightarrow \tau^+ \tilde{\tau}^- \rightarrow \tilde{\chi}^0_1 \]

We use a well motivated model: Minimal Supergravity (mSUGRA)

\[ = \text{SM} + \text{SUSY} + \text{Mass Universality} \]
[1] Dark Matter allowed region is characterized by a near degeneracy between the stau and the LSP

$$\Delta M = M_{\tilde{\tau}} - M_{\tilde{\chi}_1^0}$$

[2] Amount of Dark Matter depends on $\Delta M$

Measurement of $\Delta M$ would be a “direct” detection of CDM!

Q: Can we measure $\Delta M$ at LHC?

[1] Squark, gluino production has a large cross section

[2] $\tau \tau$ final state is dominant
Review of $2\tau/3\tau$ Analyses at LHC

[1] References:


[2] Example – $2\tau$ analysis: Optimized Cuts to reduce Standard Model background (e.g., top, W+jets)

- $E_T^{\text{miss}} > 180$ GeV
- $E_T^{\text{jet1}} > 100$ GeV, $E_T^{\text{jet2}} > 100$ GeV
- $H_T = E_T^{\text{miss}} + E_T^{\text{jet1}} + E_T^{\text{jet2}} > 600$ GeV
- $P_T^{\text{vis}} > 40, 20$ GeV

Measuring $\Delta M$

[1] Invariant Ditau Mass

a. Subtract OS histogram and LS histogram to obtain the correct tau pairs

b. Ditau mass distribution end point $M_{\text{end}}$ and peak position $M_{\text{peak}}$ can be measured

c. Assuming gaugino unification, there is a dependence on $M_g$ and $\Delta M$ {Assumption: $M_g$ is measured in another analysis}

$P_T^{\text{vis}} > 20$ GeV is vital!
**Measuring $\Delta M$ (cont’d)**

[2] Number of OS-LS counts up to the theoretical endpoint

\[ M_{\text{peak}} \text{ and } N_{\text{OS-LS}} \rightarrow \Delta M \text{ and } M_{\text{gluino}} \]

![Graph showing OS-LS counts vs. $\Delta M$](image)

Negligible $f_{\tilde{f}\rightarrow\tau}$ dependence

\[ \Delta M (\text{GeV}) \]

**Measuring $\Delta M$ (Another Way)**

[3] Slope of $P_T$ distribution for soft $\tau$ (Preliminary Study)

\[ ISAJET \ 7.69 \]

\[ \tilde{\tau} \rightarrow \tau \tilde{\chi}^0_1 \]

Slope of $P_T$ distribution contains $\Delta M$ Information.

Can we use $P_T$ to test Gaugino Unification or other mSUGRA parameters?
Summary

- SUSY models naturally provide a Dark Matter candidate (LSP)
- Dark Matter Signature at the LHC: Jets + $\tau$’s + $E_T^{miss}$
- Keys: P_{T(vis)} > 20 GeV ; $\varepsilon$ = 50%, $f_{j\rightarrow \tau}$ = 1%
- Invariant Ditau Mass & N_{OS-LS} : $\Delta M$ and $M_{gluino}$
- Ongoing Study : Slope of Low Energy $\tau$ P_{T} to measure $\Delta M$